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Accurate Simulation of Solute Transport in a Discrete-Fracture Model at Large Scale

Wesley Campbell and Kent Novakowski
Queen's University, Civil Engineering, Kingston, Canada

Modelling large-scale solute transport in fractured rocks can be challenging due to the complex nature of transport processes in both the fractures and the porous matrix, which usually occur over vastly different time scales. Using the 3-D control-volume finite-element model HydroGeoSphere (HGS), we identified computational limitations while simulating groundwater flow and solute transport over large (> 200 m) scales using a discrete-fracture model. In addition, we used 2k factorial analysis in conjunction with flow and transport simulations in a simple 2-D discrete-fracture network to identify the most important parameters controlling solute transport at two scales of interest (i.e. 50 m and 250 m), as well as the relative change in importance of these parameters with increasing scale. Using the same 2-D discrete-fracture network, we initiated the development and testing of a hybrid numerical-analytical method for simulating solute transport in fractured rocks over very large scale. Via systematic comparison of solute transport simulations in a steady groundwater flow field, we have accurately reproduced solute breakthrough curves generated by the numerical model HGS using our hybrid method at multiple transport scales (i.e. 10 m, 50 m and 250 m), while expending much less computational effort. We have also demonstrated that solute transport in a 2-D discrete-fracture network, having only a single flow path and a steady flow field, can be equivalently modelled as a single fracture with average values computed for the aperture and fluid velocity. This method is then extended to simulate solute transport in more complex, realistic, large-scale fracture networks.